

Laboratory Evaluation UniTec Sens-IT Ozone Sensor



Background

Three **Sens-IT** ozone sensors that were previously field-tested at the SCAQMD Rubidoux fixed ambient monitoring station (07/01/2015 to 07/31/2015) under ambient weather conditions, have now been evaluated in the SCAQMD Chemistry Laboratory under controlled ozone concentration, temperature, and relative humidity.

- Sens-IT (3 units tested):

- Gaseous sensors: metal oxide (**non-FEM**)

- Unit measures: ozone

Unit cost: ~\$2200

- Time resolution: 1-min

- Units IDs: U190, U057, U059



- FEM instrument:

- Ozone (Serinus 10, American Ecotech, Providence, RI)

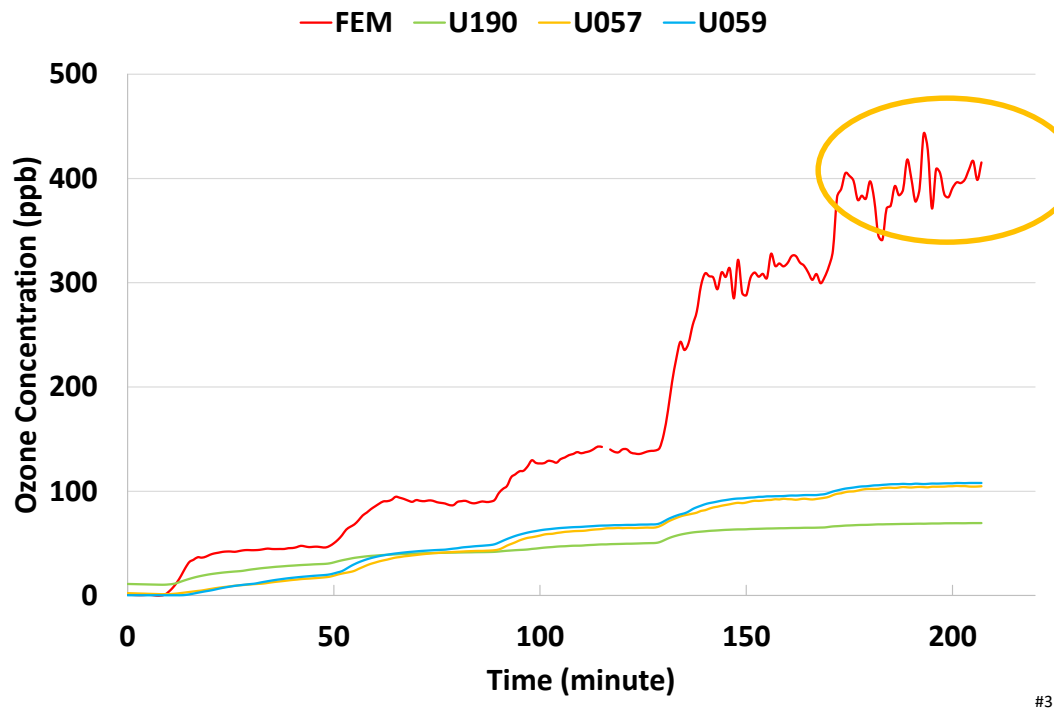
Instrument cost: ~\$7,000

- Time resolution: 1-min



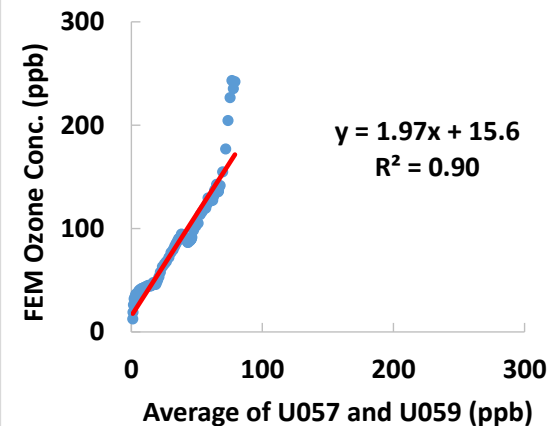
Sens-IT vs FEM (ozone; 20 °C, 40%, 1-min mean)

Sens-IT O₃ vs FEM (O₃ conc. ramping; 20 °C, 40%)



In the inner testing chamber, 400 ppb ozone was approximately the maximum concentration that Teledyne T700 U could generate. It is possible that at this high concentration, ozone output was not as stable as at low conc., causing the variations observed with FEM. Whereas, Sens-IT units were not as sensitive at this high ozone conc.

FEM vs Sens-IT Ozone Conc.
(10-250 ppb, 20 °C, 40% RH)



- At 20 °C and 40% RH, the three Sens-IT units tracked well with the ozone concentration changes between 10-250 ppb, as measured by FEM. Sens-IT units underestimated the FEM ozone concentrations.
- Units U057 and U059 had baseline readings of 0 ppb, whereas Unit U190 read around 10 ppb. As described by the manufacturer, Sens-IT units do not measure concentration below 10 ppb ozone.
- In ozone concentration range of 10-250 ppb, Sens-IT Units U057 and U059 showed good correlation with the corresponding FEM data ($R^2 > 0.90$) at 20 °C and 40% RH.

SensIT Ozone Accuracy

- Accuracy (20 °C and 40% RH)

Steady State (#)	Sensor mean (ppb)	FEM (ppb)	Accuracy (%)
1	14.9	45.3	32.9
2	43.2	89.6	48.2
3	65.7	138.5	47.4

- For ozone concentrations ranging from 0 to 150 ppb, the Units U057 and U059 showed low accuracy compared to the FEM at 20 °C and 40% RH. Accuracy ranges between 32.9 and 48.2%.

Sens-IT Ozone; intra-model variability

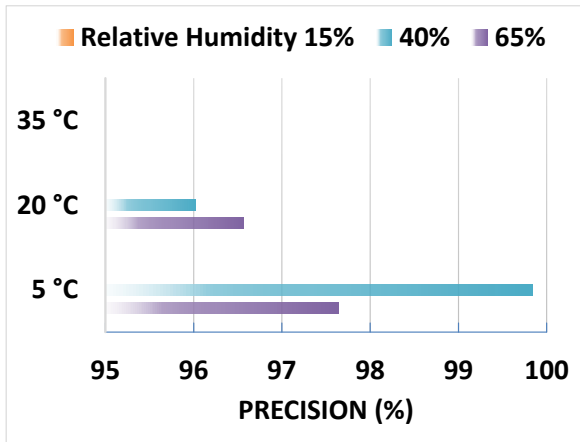
- Data recovery was 100% for each unit (U190, U057, and U059)
- Moderate to high intra-model variability was observed among the three Sens-IT units at 20 °C and 40% RH

Note: Unit U190 recorded consistently higher or lower values than the other two units (U057 and U059) and did not track well the ozone concentration ramping under different weather conditions. In the calculation of other evaluation parameters (e.g. precision, accuracy, linearity of response), unit U190 values were not included.

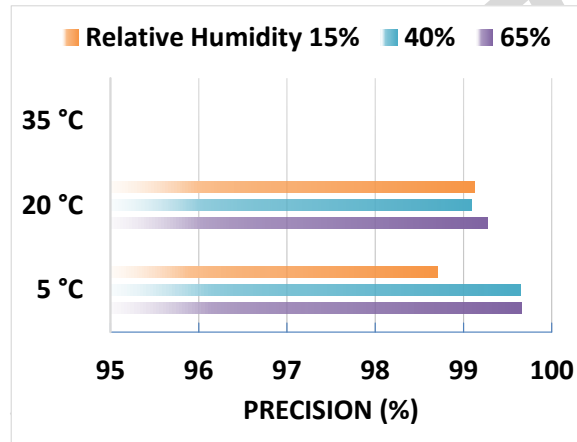
Precision: Sens-IT vs FEM (ozone; 1-min mean)

- Precision* (Effect of ozone conc., temperature and relative humidity)

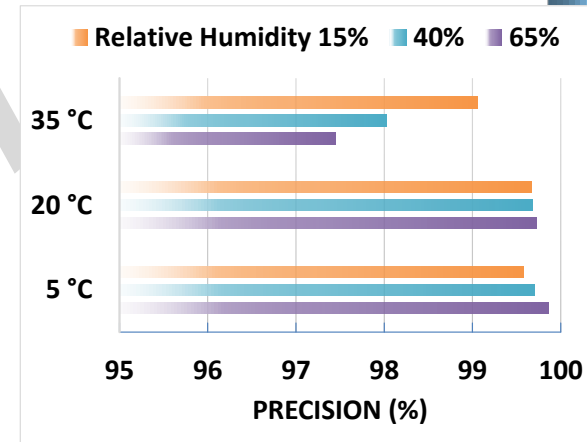
Low concentration



Medium concentration



High concentration

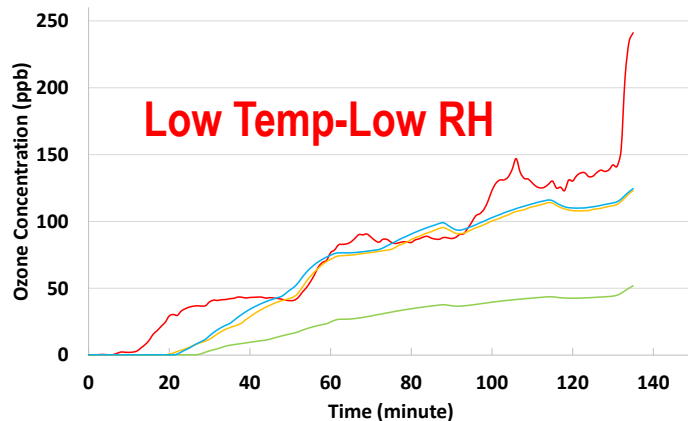


- Overall, the Sens-IT units showed good precision for most combinations of low, medium and high ozone conc., T, and RH. At 5 °C and 20 °C and 15% RH, Units U057 and U059 had the lowest precision.
- FEM's precision was high across all conditions.

Sens-IT Ozone Climate Susceptibility

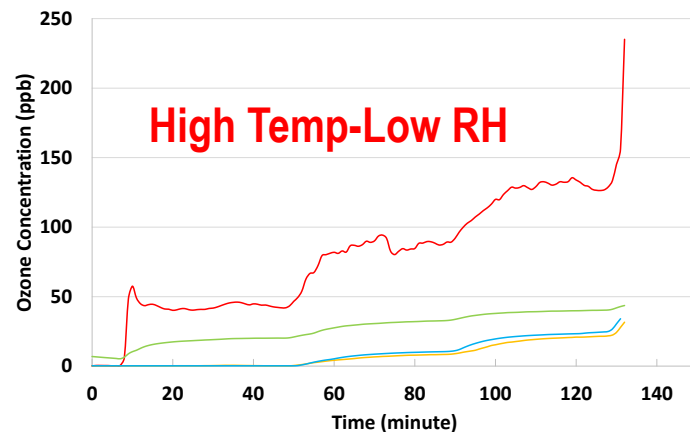
Sens-IT O₃ vs FEM (O₃ conc. ramping; 5 °C, 15%)

— FEM — U190 — U057 — U059



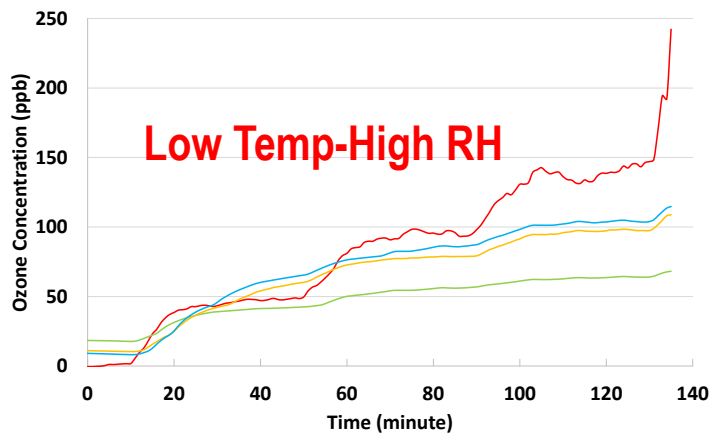
Sens-IT O₃ vs FEM (O₃ conc. ramping; 35 °C, 15%)

— FEM — U190 — U057 — U059



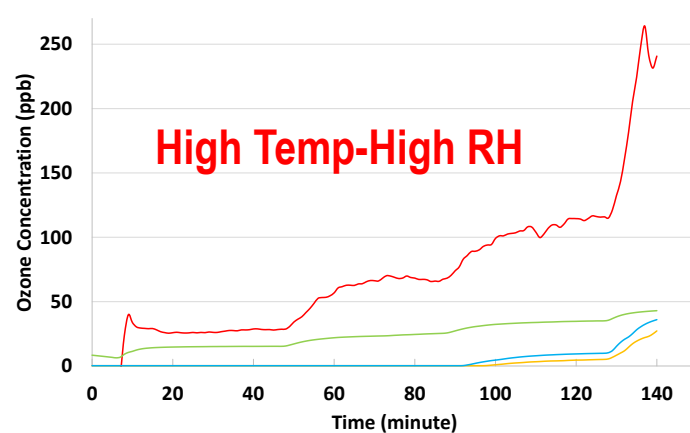
Sens-IT O₃ vs FEM (O₃ conc. ramping; 5 °C, 65%)

— FEM — U190 — U057 — U059

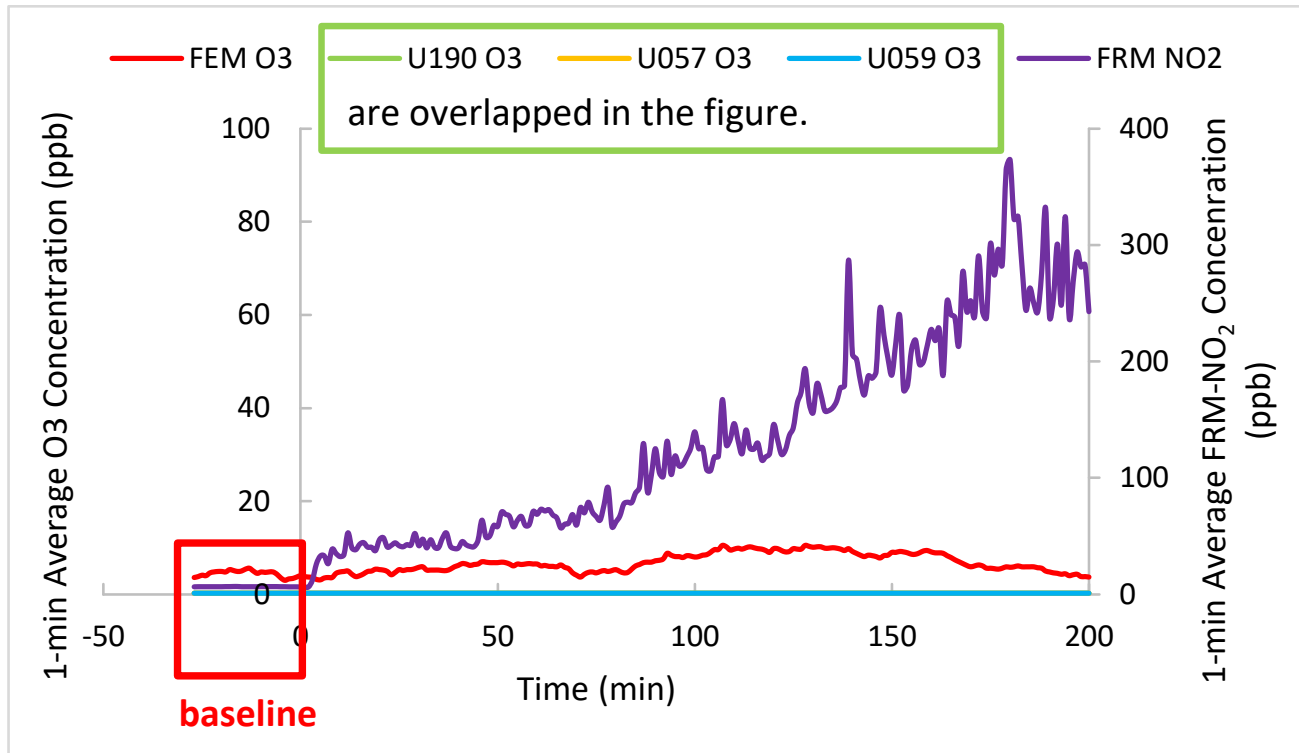


Sens-IT O₃ vs FEM (O₃ conc. ramping; 35 °C, 65%)

— FEM — U190 — U057 — U059



NO₂ Interferent (1-min mean)



In the laboratory, the effect of NO₂ interferent is evaluated by exposing sensors to increasing concentrations of NO₂ at 20 °C and 40% RH. As shown in the figure, both the FEM and sensors maintained their baseline readings throughout the NO₂ concentration ramping from 0 to 300 ppb.

Discussion

- **Accuracy:** For ozone concentrations ranging from 0 to 150 ppb, units U057 and U059 showed low accuracy compared to the FEM at 20 °C and 40% RH. Accuracy ranges from 32.9 – 48.2%. (refer to slide 13).
- **Precision:** Overall, units U057 and U059 showed good precision for most combinations of low, medium and high ozone conc., T, and RH. At 5 °C and 20 °C and 15% RH, Units U057 and U059 had the lowest precision. (refer to slide 14)
- **Intra-model variability:** Moderate to high intra-model variability was observed among the three Sens-IT units at 20 °C and 40% RH (slide 4). Unit U190 recoded consistently higher or lower values than Units U057 and U059.
- **Data recovery:** Data recovery from U190, U057, and U059 was 100% for all units.
- **Detection limit:** According to the manufacturer, the Sens-IT ozone sensor has the detection limit of 10 ppb. However, as shown in the laboratory evaluation, Unit U057 and U059 were found not to respond to ozone concentration changes up to 90 ppb in some weather conditions (slide 11).
- **Linearity of sensor response:** Sens-IT ozone sensors showed good linear correlation with the corresponding FEM ozone measurements between 10-250 ppb (R^2 : 0.80-0.96). (refer to slide 8, 10, and 12) However, under some weather conditions, the Units U057 and U059 did not have linear response below 50 ppb.
- **Intereferent:** Sensors were inert to NO_2 at 20 °C and 40% RH. When NO_2 was increased from 0 to 300 ppb, the sensors maintained their baseline readings.

Discussion

- **Sensor contamination and expiration:** Prior to the laboratory evaluation, the Sens-IT sensors were tested in the field for one month. The laboratory studies lasted for about two weeks. All three Sens-IT sensors maintained their functionalities and operated normally throughout the duration of the testing.
- **Climate susceptibility:** The three Sens-IT units were sensitive to temperature and relative humidity. Under the same ozone concentration, the Sens-IT units measured higher ozone values at low the T and RH. Sens-IT units' baseline values were also affected. The baseline values varied from 0 to 50 ppb under the tested conditions. In some weather conditions, the Sens-IT units did not measure ozone concentration changes below 90 ppb.
- **Response to loss of power:** Sens-IT units were USB powered. During the laboratory tests, the three Sens-IT units did not have any down time.